A Demonstration of Submerged Aquatic Vegetation/Limerock Treatment System Technology for Removing Phosphorus From Everglades Agricultural Area Waters

Fourth Monthly Report

Prepared for:

South Florida Water Management District
3301 Gun Club Road
West Palm Beach, FL 33406

and

Florida Department of Environmental Protection
Twin Towers Office Building
2600 Blair Stone Road, MS 3560
Tallahassee, FL 32399-2400

Prepared by:

DB Environmental Laboratories, Inc.
414 Richard Rd.
Rockledge, FL 32955

October 23, 1998

Introduction

On February 12, 1998, the District contracted with DB Environmental Laboratories, Inc. (DBEL) to design, construct, operate, and evaluate a 13-month, tank-scale (i.e., "mesocosm") demonstration of SAV/ Limerock Treatment System technology for reducing P discharge from EAA waters. The objectives of this project are twofold. First, obtain the performance data and operational experience necessary to evaluate the technical, economic, and environmental feasibility of using SAV/Limerock technology for P removal at either the watershed basin- or farm-scale. Second, guide the design and operation of a larger, field-scale SAV/Limerock demonstration project should the District choose to investigate this technology further. This report summarizes progress during the seventh month (project weeks 32-35) by DB Environmental Laboratories, Inc. (DBEL) on the Submerged Aquatic Vegetation/Limerock (SAV/LR) demonstration project.

Synopsis of Progress to Date

North Project Site

All experiments at the North Supplemental Technology Site are proceeding according to the attached schedule (Fig. 1). To date, all sampling and analyses have focused either on P species, or on analytes closely associated with P cycling in the SAV/LR process (e.g., calcium, alkalinity). During September 1998, we performed an initial sampling of 15 ancillary water quality parameters for Subtask 4C. Most parameters were found to be dynamic in both the SAV and LR unit processes, with all constituents except total suspended solids (TSS) and reactive silica (Si) exhibiting a concentration reduction as the agricultural drainage water passed through the sequential SAV - LR system (Tables 1 - 3). Color and TOC, for example, were removed both in the SAV and LR units, possibly by adsorption. Inorganic N species (NO_x and NH_4-N) declined markedly in the SAV unit process, presumably due to plant uptake and/or microbial metabolism. NO_x concentrations subsequently increased in the LR unit process, which suggests the limerock surfaces harbor nitrifying bacteria.

The hydraulic residence time (HRT) of the SAV/LR system influenced removal rates of many parameters (Tables 1 - 3). Sulfate levels, for example, exhibited little change after passing through the SAV mesocosms operated at short (1.5 day) and moderate (3.5 day) HRTs. By contrast, at the 7 day HRT, sulfate levels in the SAV component were reduced by 20%, from 112 to 89 mg/L. Constituent removal in the SAV mesocosms in turn influenced the contaminant removal performance in the downstream LR beds. For the 1.5 and 3.5 day HRT SAV tanks in which little sulfate was removed, the LR bed provided a marked reduction of this constituent. Little further reduction in sulfate was observed, however, in the LR bed following the 7 day HRT SAV mesocosm.

In September 1998, we conducted water quality sampling in the Subtask 4C tanks to assess the diel variability in effluent quality from the SAV/LR systems operated at various HRTs. Water samples were collected and field measurements were performed at 1800, 2400, and 0600 and 1200 hours. These data demonstrate that despite the marked diel swings in pH in the SAV/LR system (e.g., from 7.8 at night to 9.2 during daytime), overall system P removal performance is consistent on a diel basis (Table 4). Effluent total P ranges for the 7 day, 3.5 day and 1.5 day SAV/LR systems over the 24 hour sampling period were 11-14, 13-16, and 20 - 23 ppb, respectively. By contrast, the influent total P samples exhibited substantial diel variability, probably due to intermittent pumping activities at the S5A and ENR pump stations.

South Project Site

All mesocosms at the South Site are performing well. The shallow (10 cm), low velocity SAV/LR system has consistently provided effluent total P values at or below 10 ppb since early September. These data are shown in Figure 2, with values representing means and standard deviations from tripicate raceways. The deeper (50 cm) SAV/LR system has not been quite as

effective, providing effluent TP concentrations in the 10 - 15 ppb range during the past two months.

On October 1 and 2, 1998, we performed sampling over 24 hours to determine if the SAV/LR system P removal performance is influenced by diel variations in environmental factors. Neither the deep nor shallow low velocity systems exhibited much diel variability in either total P or SRP removal performance (Table 5). Similarly, the influent (= ENR effluent) waters exhibited consistent total P concentrations over a 24 hour period.

In August 1998 we initiated a program of biomass harvesting in the high velocity, shallow (1 cm deep) mesocosms. The periphyton that grows on the culture surface is harvested at approximately 10-14 day intervals, and subsamples are collected for analyses of dry matter content and elemental (C, N and P) composition. To date, we have observed a periphyton productivity gradient in these systems, with highest biomass production occurring in the influent region. During the six week period from mid-August to late September, dry matter productivity averaged 5.7 g/m^2-day (range 3.5 - 7.8 g/m^2-day, n=24) in the first (influent) quarter section of the raceways, and 3.6 g/m^2-day (range 2.4 - 6.8 g/m^2-day, n=24) in the 2^{nd} quarter of the raceways. Periphyton productivity drops off even further in the 3rd and 4^{th} (effluent) quarters of each raceway. Elemental composition data for the harvested periphyton are not yet available.

Table 1. Water quality characteristics of ENR influent waters following passage through a SAV/LR system operated at a 7 day hydraulic retention time. “LR effluent” samples were collected following a 5 hr residence time in the limerock bed. Values represent mean (std. dev.), n=3 (influent) or n=2 (effluents).

Parameter	***influent***	***SAV effluent***	***LR effluent***
TSS (mg/L)	2.0 (1.5)	4.0 (2.8)	4.0 (3.5)
TDS (mg/L)	1013 (12)	812 (4)	776 (28)
Turbidity (NTU)	0.79 (0.06)	0.61 (0.16)	0.62 (0.00)
TOC (mg/L)	39.9 (0.75)	38.7 (1.8)	34.7 (0.92)
Color (CPU)	308 (4)	261 (7)	243 (4)
Chloride (mg/L)	283 (3)	253 (4)	250 (0)
Potassium (mg/L)	12.2 (0.1)	9.95 (0.07)	10.5 (0.00)
Magnesium (mg/L)	34.2 (0.59)	31.5 (0.50)	29.8 (0.07)
Dissolved Al (ug/L)	304 (4)	206 (4)	211 (2)
Dissolved Fe (ug/L)	39 (3)	13 (1)	14 (1)
Reactive Si (mg/L)	22.4 (0.29)	23.0 (1.13)	22.4 (0.14)
Sulfate (mg/L)	112 (16)	88.6 (21.7)	88.6 (4.9)
Total Kjeldahl N (mg/L)	2.66 (0.13)	2.26 (0.24)	2.02 (0.02)
NH_4-N (mg/L)	0.284 (0.019)	0.020 (0.001)	0.022 (0.006)
NO_x-N (mg/L)	0.523 (0.024)	0.007 (0.006)	0.171 (0.031)

Table 2. Water quality characteristics of ENR influent waters following passage through a SAV/LR system operated at a 3.5 day hydraulic retention time. “LR effluent” samples were collected following a 5 hr residence time in the limerock bed. Values represent mean (std. dev.), n=3 (influent) or n=2 (effluents).

Parameter	***influent***	***SAV effluent***	***LR effluent***
TSS (mg/L)	2.0 (1.5)	6.0 (0.0)	2.0 (1.4)
TDS (mg/L)	1013 (12)	896 (7.7)	909 (3.5)
Turbidity (NTU)	0.79 (0.06)	0.71 (0.22)	0.66 (0.16)
TOC (mg/L)	39.9 (0.75)	39.0 (1.2)	39.3 (1.8)
Color (CPU)	308 (4)	288 (7)	270 (5)
Chloride (mg/L)	283 (3)	270 (0)	268 (4)
Potassium (mg/L)	12.2 (0.1)	10.6 (0.21)	11.0 (0.21)
Magnesium (mg/L)	34.2 (0.59)	33.4 (0.21)	31.2 (0.57)
Dissolved Al (ug/L)	304 (4)	242 (12)	257 (1)
Dissolved Fe (ug/L)	39 (3)	25 (8)	22 (6)
Reactive Si (mg/L)	22.4 (0.29)	25.5 (0.28)	24.3 (0.50)
Sulfate (mg/L)	112 (16)	110 (12.0)	88.4 (5.1)
Total Kjeldahl N (mg/L)	2.66 (0.13)	2.41 (0.13)	2.10 (0.03)
NH_4-N (mg/L)	0.284 (0.019)	0.017 (0.001)	0.016 (0.003)
NO_x-N (mg/L)	0.523 (0.024)	0.025 (0.033)	0.132 (0.001)

Table 3. Water quality characteristics of ENR influent waters following passage through a SAV/LR system operated at a 1.5 day hydraulic retention time. “LR effluent” samples were collected following a 5 hr residence time in the limerock bed. Values represent mean (std. dev.), n=3 (influent) or n=2 (effluents).

Parameter	***influent***	***SAV effluent***	***LR effluent***
TSS (mg/L)	2.0 (1.5)	5.0 (2.1)	3.0 (2.1)
TDS (mg/L)	1013 (12)	959 (10)	943 (15)
Turbidity (NTU)	0.79 (0.06)	0.69 (0.01)	0.60 (0.11)
TOC (mg/L)	39.9 (0.75)	38.7 (1.8)	34.7 (0.92)
Color (CPU)	308 (4)	299 (4)	277 (1)
Chloride (mg/L)	283 (3)	277 (2)	273 (4)
Potassium (mg/L)	12.2 (0.1)	11.3 (0.3)	11.4 (0.2)
Magnesium (mg/L)	34.2 (0.59)	34.3 (0.28)	32.6 (1.1)
Dissolved Al (ug/L)	304 (4)	281 (10)	284 (9)
Dissolved Fe (ug/L)	39 (3)	30 (3)	29 (6)
Reactive Si (mg/L)	22.4 (0.29)	26.4 (0.07)	24.6 (0.57)
Sulfate (mg/L)	112 (16)	110 (1.4)	95.2 (6.8)
Total Kjeldahl N (mg/L)	2.66 (0.13)	2.40 (0.06)	2.11 (0.01)
NH_4-N (mg/L)	0.284 (0.019)	0.025 (0.001)	0.014 (0.003)
NO_x-N (mg/L)	0.523 (0.024)	0.019 (0.008)	0.234 (0.044)

Table 4. Diel phosphorus removal performance of SAV/LR systems at the North Supplemental Technology Site that receive ENR influent waters. Data were collected during the period September 22 and 23, 1998. Values represent mean (std. dev.), n=3 (influent) or n=2 (effluent) for systems operated at three hydraulic retention times (HRTs).

7 day HRT SAV/LR system

Time	*Total P (ppb)*		*Soluble Reactive P (ppb)*	
	influent	effluent	influent	effluent
1800	131 (19)	11 (6)	93 (19)	4 (2)
2400	112 (10)	13 (2)	77 (9)	7 (6)
0600	96 (3)	14 (1)	63 (3)	4 (2)
1200	148 (8)	12 (2)	113 (2)	5 (2)

3.5 day HRT SAV/LR system

Time	*Total P (ppb)*		*Soluble Reactive P (ppb)*	
	influent	effluent	influent	effluent
1800	131 (19)	13 (0)	93 (19)	5 (0)
2400	112 (10)	16 (2)	77 (9)	5 (0)
0600	96 (3)	15 (0)	63 (3)	8 (3)
1200	148 (8)	15 (2)	113 (2)	7 (1)

1.5 day HRT SAV/LR system

Time	*Total P (ppb)*		*Soluble Reactive P (ppb)*	
	influent	effluent	influent	effluent
1800	131 (19)	20 (0)	93 (19)	7 (1)
2400	112 (10)	20 (3)	77 (9)	11 (1)
0600	96 (3)	23 (1)	63 (3)	11 (1)
1200	148 (8)	21 (0)	113 (2)	12 (2)

Table 5. Diel phosphorus removal performance of shallow and deep low velocity SAV/LR systems that receive ENR effluent waters. Data were collected during the period October 1 and 2, 1998. Values represent mean (std. dev.), n=2. (Duplicate influent samples were collected only for the deeper systems).

Shallow (10 cm depth), low velocity SAV/LR system

Time	*Total P (ppb)*		*Soluble Reactive P (ppb)*	
	influent	effluent	influent	effluent
1800	19	9 (1)	5	2 (0)
2400	19	11 (1)	6	2 (0)
0600	20	10 (1)	6	3 (1)
1200	20	10 (1)	6	2 (1)

Deep (50 cm depth), low velocity SAV/LR system

Time	*Total P (ppb)*		*Soluble Reactive P (ppb)*	
	influent	effluent	influent	effluent
1800	17 (0)	12 (1)	6 (1)	2 (0)
2400	18 (1)	13 (1)	7 (1)	2 (0)
0600	19 (0)	12 (0)	5 (0)	2 (0)
1200	19 (0)	14 (0)	7 (1)	3 (1)

A Demonstration of Submerged Aquatic Vegetation/Limerock Treatment System Technology for Removing Phosphorus From EAA Waters

PRIVATE _Executive Summary: Months 1 - 7

October 26, 1998

- DB Environmental Laboratories, Inc. (DBEL) was awarded a contract on February 12, 1998, to demonstrate the phosphorus (P) removal effectiveness of the Submerged Aquatic Macrophyte/Limerock Technology. This candidate "Supplemental Technology" consists of a wetland dominated by submerged aquatic vegetation (SAV), followed by a limerock (LR) bed.

- This project entails optimization and demonstration of SAV/LR system performance in experimental mesocosms located at the North and South Everglades Nutrient Removal (ENR) Supplemental Technology Sites.

- Mesocosm facility construction began in March 1998, and the first experiments were initiated during June 1998.

- Experiments at the North Project Site focus on documenting the effects of hydraulic retention time, water depth, plant harvest regime, and limerock characteristics on P removal from agricultural runoff (70 - 150 ppb total P concentration).

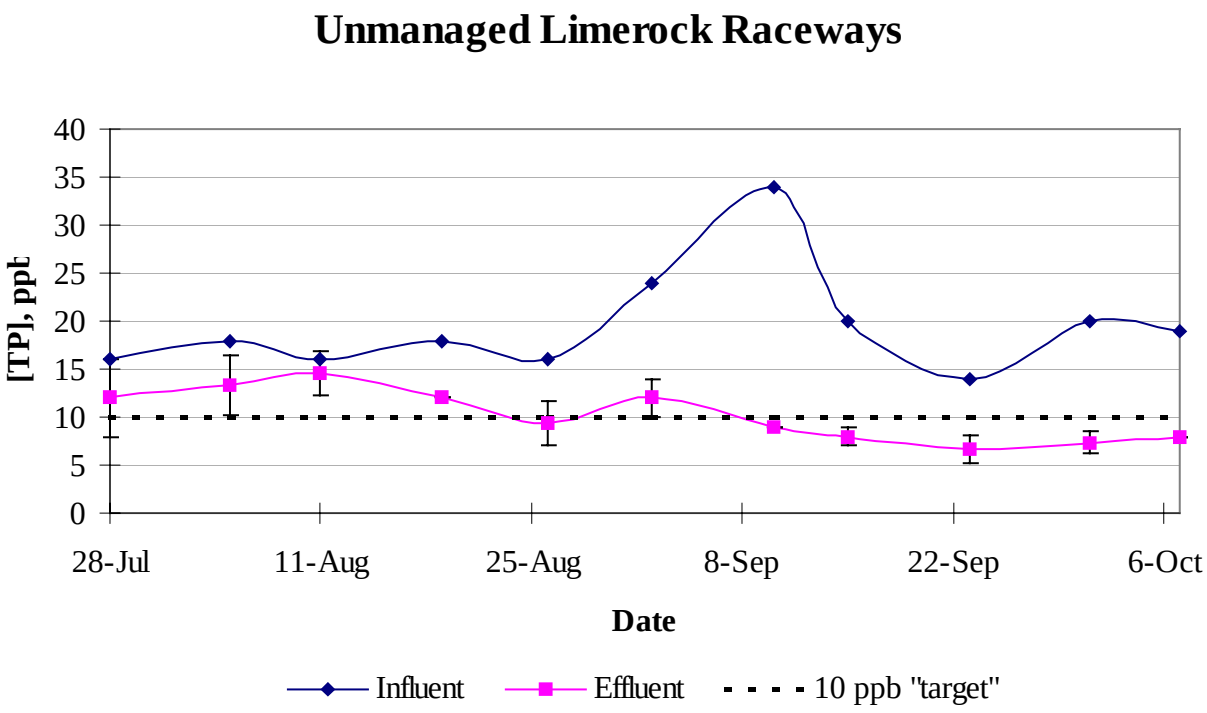
- Experiments at the South Project Site address the ability of three different SAV/LR configurations to treat ENR effluent waters (15 - 40 ppb total P concentration) to levels below 10 ppb total P. The SAV configurations being evaluated include low velocity/shallow, low velocity/deep and high velocity/shallow systems.

- Since start-up in June, the SAV/LR systems at the North Site have produced effluent TP concentrations comparable to those produced by the ENR project (10 - 26 ppb). These effluent levels have been achieved at extremely short HRTs (1.5 - 7 days), which suggests that the area requirement of a full-scale SAV/LR system would be markedly lower than that of an STA.

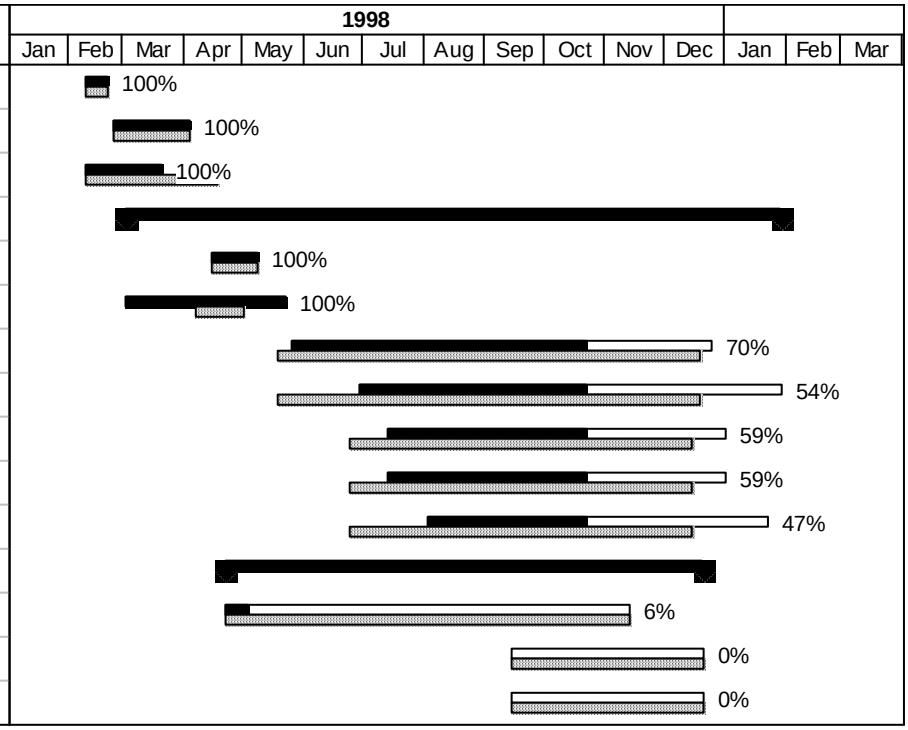
- At both the North and South Project Sites, shallow SAV systems (0.1 - 0.4 m depth) have provided lower effluent total P levels than deep (0.8 - 1.2 m depth) systems.

- Following a start-up period, the shallow, low velocity SAV/LR system at the South Site has consistently provided effluent total P values at or below 10 ppb.

- The mesocosms at the North and South Project Sites are providing performance, operational and design information which will enable us to evaluate the technical, economic and environmental feasibility of the SAV/LR technology by the scheduled project completion date (March 12, 1999).


Unmanaged Limerock Raceways
40
35
30
25
20
15
10
5
0
[TP], ppb
28-Jul
11-Aug
25-Aug
8-Sep
22-Sep
6-Oct
Date
Influent
Effluent
10 ppb "target"

ID	Task Name
1	Task 1: Prelim. Project Work Plan
2	Task 2: Final Project Work Plan
3	Task 3: Project QAPP
4	**Task 4: Design and Operation of SAV/LR System**
5	4A: Limerock Characterization
6	4B: Demonstration Facility Construction
7	4C: HRT Study
8	4D: Low Nutrient Water Study
9	4E: Plant Harvest Study
10	4F: Plant Depth Study
11	4G: Limerock Comp. and Size Study
12	**Task 5: Technology Assessment**
13	5A: Field Observation of ENR SAV
14	5B: Tech. and Environmental Assessments
15	5C: Economic Analysis



Legend

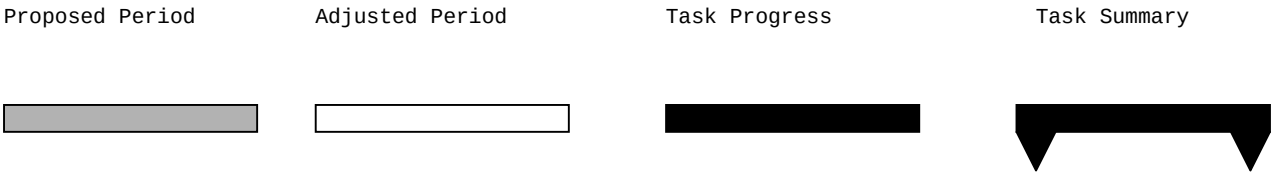
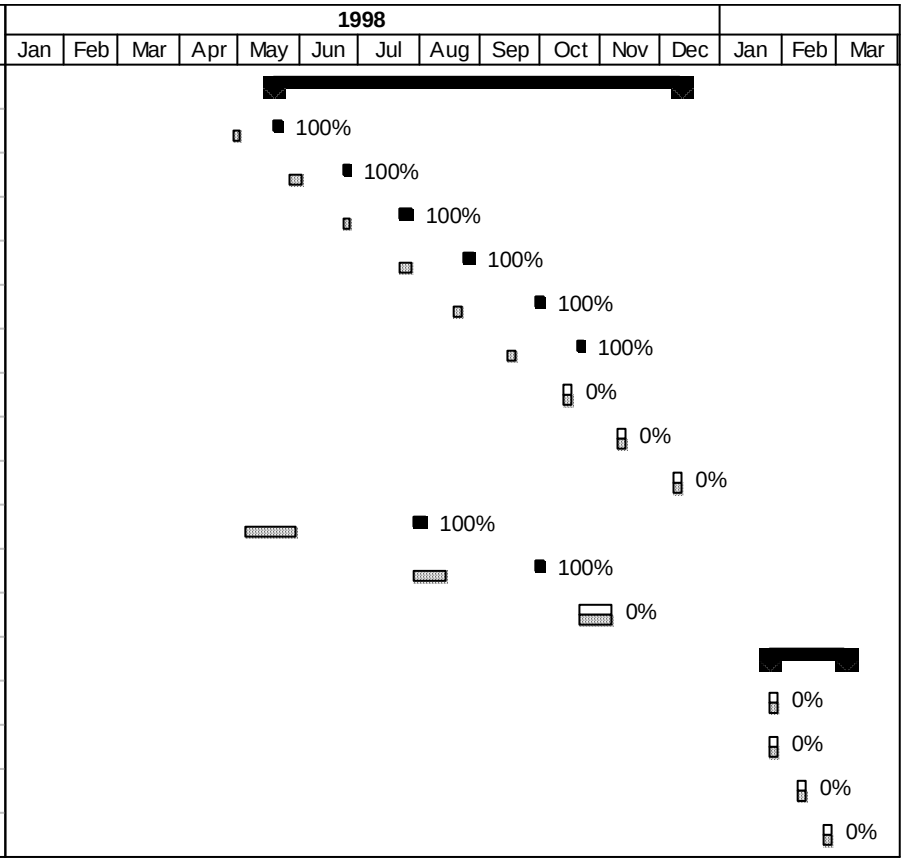


Figure 1. SAV/Limerock Project Schedule

ID	Task Name
16	**Task 6: Status Reports and Review Meetings**
17	1st Quarterly Report
18	1st monthly Report
19	2nd Monthly Report
20	2nd Quarterly Report
21	3rd Monthly Report
22	4th Monthly Report
23	3rd Quarterly Report
24	5th Monthly Report
25	6th Monthly Report
26	1st Quarterly Meeting
27	2nd Quarterly Meeting
28	3rd Quarterly Meeting
29	**Task 7: Final Work Products**
30	Raw data, Hard copy and Electronic
31	Draft Final Report
32	Final Project Meering
33	Final Report



Legend

Proposed Period

Adjusted Period

Task Progress

Task Summary

Figure 1 (cont.) SAV/Limerock Project Schedule